



ARCHER HSI: from search and rescue to emergency response – *experiences and challenges*

Carol S. Mladinich and Susan C. Stitt

Rocky Mountain Geographic Science Center, Lakewood, CO, 80225
csmadinich@usgs.gov

U.S. Department of the Interior
U.S. Geological Survey

Title slide

Outline

- Introduce hypothesis
- Setting the Stage: Coffeyville, KS
 - USGS – Civil Air Patrol Involvement
- CAP ARCHER instrument
 - Preprocessing
 - Initial classification work
 - Follow-on classification work
- Evaluation in terms of hypothesis
 - Front-end
 - Back-end
- Recommendations



Hyperspectral Imaging (HSI)

- **Pluses**

- Increases potential for detailed identification of materials
- Increases potential for estimation of material abundance

- **Minuses**

- Difficult to obtain
- Difficult to process

- **Hypothesis:**

- *Can V-NIR HSI sensors effectively be used to identify contaminants for emergency response situations, are there limitations to its use?*



Issues surrounding HSI data

Hypothesis: *How can NIR HSI sensors be effectively used to identify contaminants for emergency response situations?*

How viable is the use of NIR (400 – 1100 nm) HSI sensors for emergency response?

"A malfunction allowed the oil to spill from the Coffeyville Resources refinery on Sunday, while the plant was shutting down in advance of the flood heading toward it on the Verdigris River." [June 30, 2007]



Coffeyville flooding 7/3/2007



Coffeyville flooding - refinery 7/3/2007

"The flood engulfing homes to the rooftops carried an extra curse Tuesday as a slick of 42,000 gallons of thick crude oil floated downstream with the mud and debris, coating everything it touched with a slimy, smelly layer of goo."



Roxana Hegeman, AP, July 3, 2007

Setting the stage.....end of June was a wet one for many of the southern Great Plains states



SE Kansas, southern city limits on KS-OK state line, 30 mi NE Tulsa

Flood debris and oil flowing down Verdigris River towards Lake Oologah, drinking water for several cities including Tulsa

EPA Region 6 request for imagery

- **Over Coffeyville KS and Verdigris River**
 - Flooding and crude oil spill
 - Obtain imagery (any) and Process imagery for emergency responders
- **USGS Liaison to Northcom**
 - Request through Air Force to Civil Air Patrol
 - Post Katrina MOU
 - Facilitate emergency response



Civil Air Patrol

■ Background

- 1941: CAP Established Dec 1st
- 1948: Auxiliary of the United States Air Force (PL 557)
- Federally chartered nonprofit corporation
- **ALL VOLUNTEERS**

■ Advanced Technology Group

- Airborne Real-time Cueing Hyperspectral Enhanced Reconnaissance → **ARCHER**



CAP Charter

resulted in the creation of the Civil Air Patrol on Dec. 1, 1941

July 1, 1946, President Harry Truman signed Public Law 476 that incorporated CAP as a benevolent, nonprofit organization.

And on May 26, 1948, Congress passed Public Law 557 which permanently established CAP as the Auxiliary of the new U.S. Air Force.

ARCHER researched and developed under guidance of all volunteer Advanced Technology Group

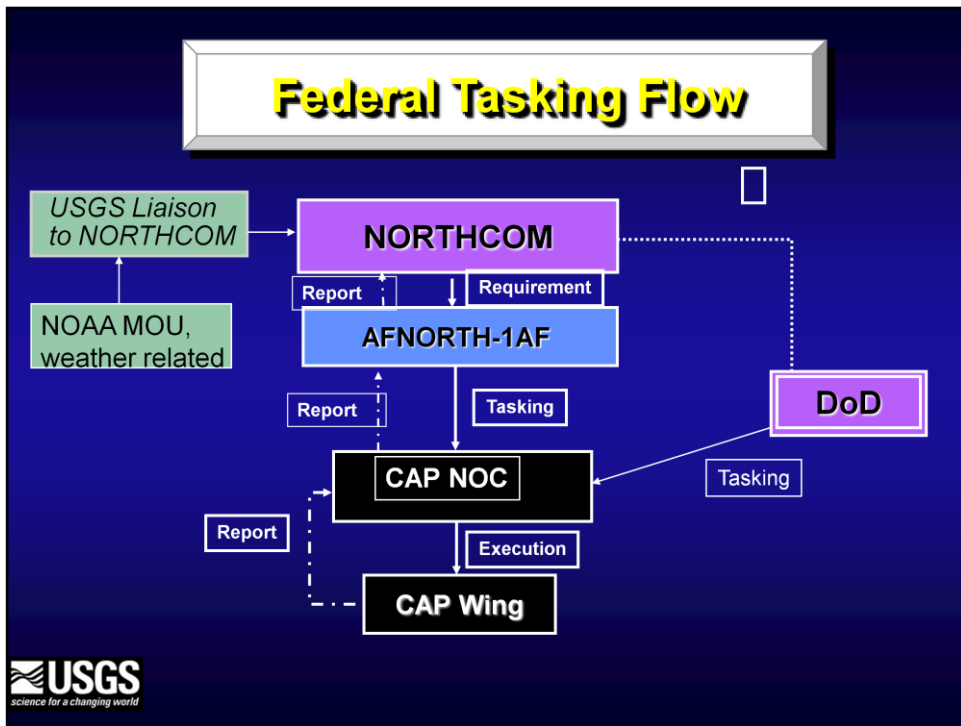
in cooperation with Naval Research Lab, Air Force Research Lab, and US Coast Guard Research & Development Ctr

16 systems plus a spare

2003 RFP, late summer 2004 awarded, 2006 last acceptance == \$6m for technology

Software by Space Computer Corporation, Hardware NovaSol Corp

Flown on Gippsland Aeronautics GA-8



More than 60% of AFNORTH missions on their Air Tasking order are CAP Missions.

NOC – National Operations Center

ARCHER System

- Growing class of light weight, quick production NIR HSI sensors – aerial and satellite
- Integrated hardware and software
 - Advanced hyperspectral imaging (HSI) system
 - 1-m spatial resolution
 - 52 spectral bands (500 to 1100 nm)
 - Panchromatic high-resolution imaging (HRI) camera
 - 8-cm spatial resolution
 - Standard mission altitude of 2500 feet AGL and 100 knot groundspeed
 - Global positioning system (GPS) and inertial navigation system (INS)
 - Provide aircraft location, altitude, pitch, yaw, and roll



so that each image pixel can be accurately positioned (geo-registered) on a virtual map, in real time, during a mission.

1x1 m - HSI

8x8 cm or 3"x3" - Pan

Primary Design: Search and Rescue

- *Find downed planes*
- **Airborne system – Real-time Processing**
 - Georegistered image plotted on the airborne station monitor in real time
 - Identified targets highlighted with yellow or red squares
 - Pansharpened image chip of identified target displayed in separate window
 - Target location recorded in latitude, longitude, and elevation

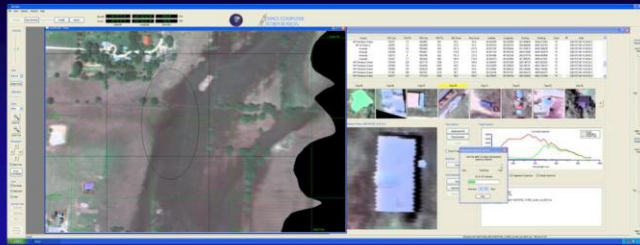


REAL TIME

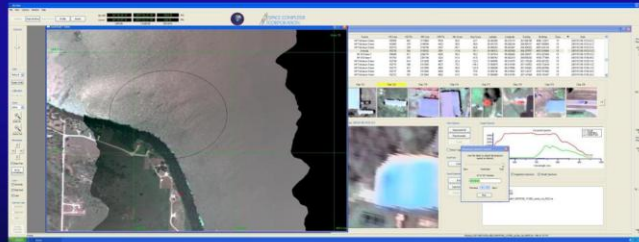
- 1) spectral signature matching (matching reflected light to spectral signatures)
- 2) anomaly detection (calculates a statistical model of all the pixels in the image to see if there is a probability that a pixel does not fit)
- 3) change detection (a pixel-by-pixel comparison of current ground conditions against ground conditions that were obtained in a previous mission over the same area)

Signature Match Detection – algorithm detects spectra that match a predetermined spectrum, logarithmic scale

Anomaly Detection –algorithm detects spectra that are anomalous to general background, sensitivity based threshold

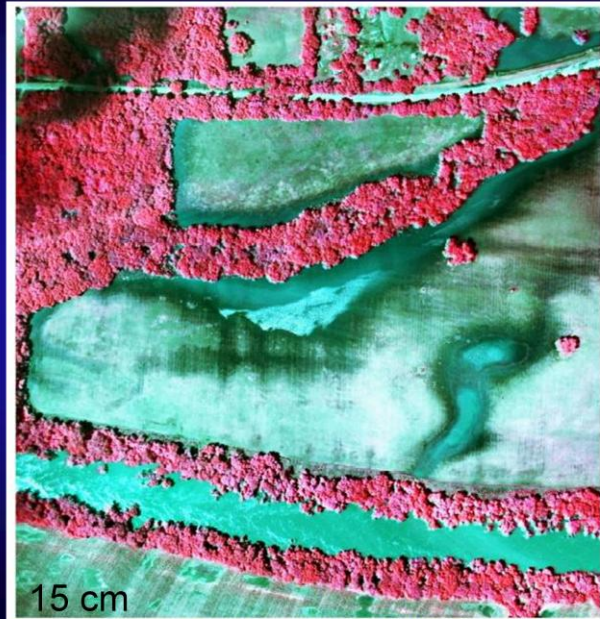


Possible oil
contamination



Screen shots received from CAP crew

Imagery



 **USGS**
science for a changing world

Processing Issues

- 160 minutes of flying time captured
 - 1 file for every minute of flying time
 - Input: 1,147 total files, 70 GB
 - Output: 833 files, 311 GB
- Delivery
- Temporary use of ARCHER software
 - GeoRegArcher - georegistration
 - GeoReplay – flightline orientation



Products

- **Pan – 15 cm**
 - Files mosaicked (160)
 - Subset into manageable files
- **HSI – 1 m**
 - 4-banded (B,G,R,IR) image generated
 - Files mosaicked (160)
 - Subset into manageable files
 - Emergency management personnel able to display desired bands – natural color/color IR
- **Classification of potential spread, contamination sites**



Preliminary Classification

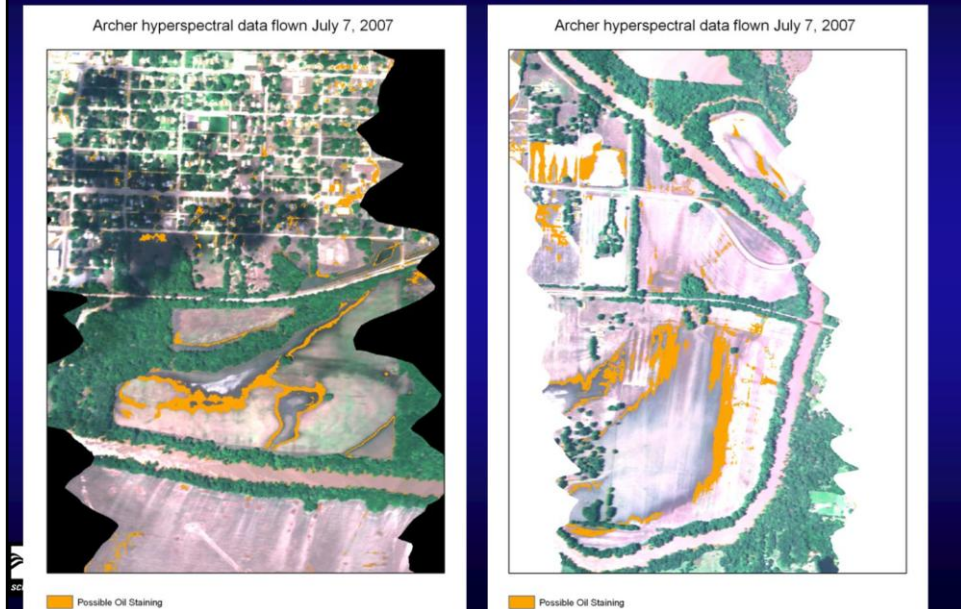


Image quality

Signal to noise ratio – 100:1

Smearing/Blurring of data

Exceed aircraft speed

Lack of reference data

No ground reference data or spectra

False positives

Sensor not designed for water reflectance overload sensor – as seen at Lake Oologah

Classification Difficulties

- Image quality
 - Signal to noise ratio – 100:1
 - Smearing/Blurring of data
 - Exceed aircraft speed
- Lack of reference data
 - No ground reference data or spectra
 - False positives - asphalt roads
 - Sensor not designed for water



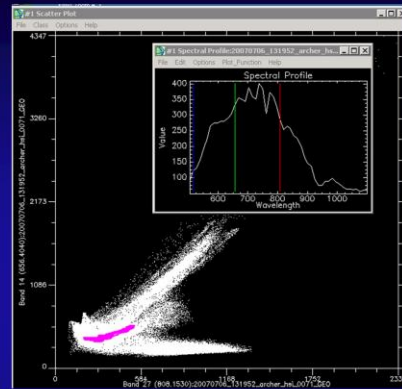
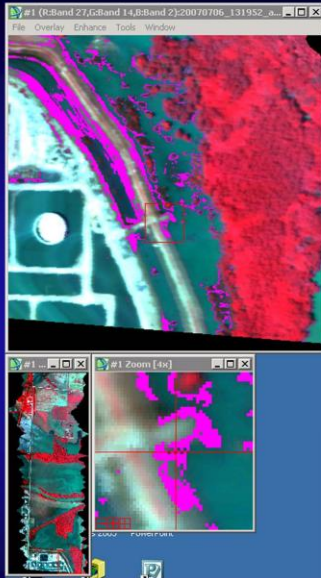
- False positives => asphalt roads, some of the dark ponds
 - Water => auto-exposure (brightness) compensation goes bonkers with too much orange red compensation
- Fresh water vs salt water is there a difference?
- Can signatures be developed
- Partial Unmixing seems good solution
- In the case of an oil spill, it is difficult to select pure pixels of oil for training samples without including pixels of other mixed classes. Oil sticks on the edges and stream borders following a primarily linear shape rather than a polygon shape. It is, therefore, difficult to select separate samples of polluted soil and water on ponds, as they both appear black. In comparison to minerals, which have consistent spectral signatures, the spectral properties of oil spills are much less consistent. For example, factors such as variations in weather conditions, changes in oil characteristics, and type of oil spill create oil spectral variation that cannot be predetermined easily in a spectral library.

Follow-on Classification Work

- **Approach**

- Reproduce methods reported by Salem and others, IJRS, 2005.
 - End member analysis
 - 2-D scatter plot to identify regions of interest and train classifier
 - Mask out known items, i.e. trees
 - ML classification
- Use of sampling sites as ground reference locations





Potential oil based on EPA water sampling site

Can ARCHER imagery be used effectively for emergency response, are there limitations to its use?

- **Front End – Yes, but...**
 - **Protocol – proof of concept**
 - **Weather**
 - **Aerial photography**
 - **Mail**
 - **Software**
 - **Processing**



Protocol / CAP – how do we do this?

primary goal of this activity

Weather – no control, started flying July 3 and 4, came back and flew July 6 and 7

Aerial photography trained to fly search and rescue, zamboni search pattern – not same as S&R

Mail – may not get data when expected -- next day, really 2nd day during the week

Software – make sure have correct tools, what to use!?? SCC provided trial copies of GeoReg (not for prime time) and GeoReplay – instrumental in identifying flight lines, turn arounds

Processing – know what products needed - 1st timers, band subset, mosaic, clip – PCI Geomatica

Ground reference data &/or Spectral library

Recommendations

- Procedure / CAP
 - Implementation under MOU works if know about it
 - Clearly define imagery distribution constraints
- Weather
- Aerial photography
 - Provide training document on basic aerial photo collection
- Tools



Protocol / CAP – how do we do this?

primary goal of this activity

Procedure / Cap – established, dedicated volunteers
what are image distribution constraints?

Weather nothing can do - no control, started flying July 3 and 4, came back and flew July 6 and 7

Aerial photography – new to crews - trained to fly search and rescue, zamboni search pattern – flying AP not same as S&R, provide training manual on basics of aerial photography – things to do/avoid, add it to ARCHER crew training

Mail – may not get data when expected -- next day, really 2nd day during the week

Software – make sure have correct tools, what to use!?? SCC provided trial copies of GeoReg (not for prime time) and GeoReplay – instrumental in identifying flight lines, turn arounds

Can ARCHER imagery be used effectively for emergency response, are there limitations to its use?

- **Back End – Maybe...**
 - **Processing**
 - **Ground reference data**
 - If possible have someone on ground with GPS or hand held spectrometer (CAP has) to get samples of what is important (oil, contaminant)
 - **Develop spectral library for common chemicals / contaminants**
 - **Develop procedures for processing data for desired products**



Protocol / CAP – how do we do this?

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Ground reference data &/or Spectral library

Follow-on Work

- **HSI processing**
 - Little work on oil spills
 - **EPA funded MO DNR Pilot Project**
 - Identify potential environmental applications and develop signature database of contaminants or environmental conditions
- **Future Use of ARCHER**
 - **Develop standard HSI collection techniques**
 - Mission planning, deployment
 - Have spectral library loaded on airborne system
 - Collect Ground reference/spectra at time of flight
- **Investigate other V-NIR HSI sensors**



Expand literature search

V-NIR HSI sensors – more coming along, both airborne and satellite that are small, quick, and easy to deploy (don't need cooling)

Is there a difference between fresh water and salt water oil spills
flooding situation – multiple contaminants

Signature database of contaminants or environmental conditions – is it possible?

Recommendations

- Processing – who, what, how, & when
 - On-site
 - Imagery for on-site responders - ASAP
 - Install GeoSharpen w/ GeoPDF capability
 - Off-site
 - GeoReg, GeoSharpen, and possibly GeoReplay
 - Development of contaminant spectral library



Processing –

Who will process the data

What are they going to process

How are they going to process

When are products needed – primary and secondary

On-Site: Have output capability from ground station (GeoSharpen), Imagery for on-site responders **ASAP**

- Potential upgrade Install GeoSharpen w/ GeoPDF capability on ground stations

Off-Site: Software need to purchase at least GeoReg, GeoSharpen, and GeoReplay

- make sure have lots of disk space!!

Mail - Know data origination, limitations of FedEx/UPS – know exactly what is best way to send data and tell crew, provide charge number

Ground reference data &/or spectral library – will make HSI processing go smoother